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WORK IN PROGRESS: SOIL ROUGHNESS AND POROSITY MEASUREMENT WITH ACOUSTICS

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INTRODUCTION

Soil erosion by water can be held to an acceptable level in cropped fields with appropriate combinations of structures, cropping, and management practices. Infiltration of water into the soil, thereby preventing runoff and consequent erosion, is directly influenced by tillage operations that are part of management. Tillage determines both the amount of crop residues that remain on the soil surface and the roughness of the surface. Residues on the surface provide protection from rain, and both residues and roughness slow water movement. "Roughness" as used in RUSLE (Revised Universal Soil Loss Equation) actually refers to two features of the soil surface: its geometric shape (pits, ridges, and mounds as they contribute to the ponding of water) and the porosity of the surface (the size and number of interconnected pores as they contribute to infiltration of water into the soil).

Measurement of roughness with current practices such as rill meters, comparative photographs or laser profile meters, provide a measure of the geometry of the soil surface. The porosity of the surface is not characterized by any of these methods. Acoustical measuring techniques have the potential for characterizing both the geometric shape and the porosity of a soil surface. The objective of this paper is to report the current status of research with acoustical soil measurements conducted at the Columbia Plateau Conservation Research Center at Pendleton Oregon.

METHODS

All measurements are made in the frequency range detectable by the human ear (20 to 20,000 cycles per second). Two types of sound measurements, direct sound absorption within the soil and reflection from the soil surface, are being investigated. The measurements of sound absorption by the soil are made with a buried microphone and a high amplitude speaker-amplifier system (250 watt). Three different uniform soil materials; mason sand, 2mm silt aggregate, and silt less than 1mm, were used to test buried microphone measurements. According to the measurements, the relative conductivities to air of these uniform materials, were 0.68, 0.10, and 0.01 respectively with a variability of +/- 20 percent. This can be interpreted as the sand with a reading of .68 being 6.8 times more porous than the silt aggregate, which was 10 times more porous than the silt.

Buried microphone measurements in a fallow cultivated field (Walla Walla silt loam that had been plowed and cultivated to a surface roughness of about 1 inch) were extremely variable, ranging between 0.50 and 0.001, or from similar to the porosity of the sand to less permeable than the silt. The observations indicate the large differences in porosity that occur from place to place in a cultivated field.

The area sampled by a buried microphone depends on the porosity of the soil surface around the microphone. Where the soil is finely pulverized or crusted only a few square inches of soil control the measurement because the sound is totally damped out within an inch of the surface. Where large clods and residue support cracks and holes into the soil, sound may travel a foot or more along a crack to reach a microphone. Note that it is the cracks or holes in the soil that determine the values measured just as it is the cracks and holes that allow water to move into the soil.

Each total observation requires from 15 minutes to 1 hour to complete. For good sound absorption readings, the microphone must be buried with as little soil disturbance as possible. Any cracking of the soil surface during installation destroys the observation as it is the crack, not the original soil pores, that will conduct sound into the soil. Once a microphone has been buried, several readings are taken for each of 10 frequencies between 100 and 5,000 cycles per second. The magnitude of the signal at each frequency at different depths are analyzed to obtain relative conductivity values.

Measurements of sound reflected from the soil surface utilize different microphones and speakers than those used for measuring sound absorption. The speaker has only a 1 inch diameter throat so it will produce spherically shaped sound waves. Standard condenser microphones are used. The speaker and one microphone are mounted 2.00 m apart 0.50 m above a soil surface on a rigid light-weight frame. A second microphone is placed directly below the first, 0.10 m from the soil surface. Exact positioning is important since it is the difference between the signals of the two microphones that is important.

A single reflection measurement can not be used to represent a surface. Reflected sound is influenced by adjacent objects, ambient noise, wind, air temperature profiles, and both the porosity and geometric shape of the soil surface As many as 50 separate samples are collected and averaged to produce one stable average measurement of a surface. Fortunately, each measurement can be taken in less than one second and required computations performed in a few seconds. Microphone signals are recorded at the rate of 32,000 points per second. Only 8,000 data points are needed to provide the frequencies present at each microphone. Within five minutes an average reflection pattern for any surface can be obtained.

Graphical comparisons of average signals reveal clearly detectable qualitative differences between rough plowed, crusted fallow, and freshly tilled smooth fallow surfaces. Conversion of these qualitative differences to repeatable quantitative values that relate to water infiltration rates or soil loss rates to erosion remains to be done. Complex theoretical computations are necessary to separate the effects of roughness and porosity. Currently, measurements must be taken above a soil surface when it is dry and when it is very wet (essentially when it is porous and when it is nonporous) to separate the two factors. New theoretical descriptions of surface reflection of sound are being developed to more clearly incorporate the separate effects of reflection from an irregular surface and absorption by a porous surface. These descriptions will be evaluated and incorporated into measurements of surface reflection as soon as they are available.

SUMMARY

The use of acoustic measurements for characterizing the geometry and the porosity of soil surfaces is a developing technology. Qualitative differences between surfaces can be illustrated, but quantitative descriptions usable for routine field evaluation may be two years or more away. The complexity of sound reflection from and absorption of a rough, porous surface slows progress in achieving an accurate theoretical description of the process.